CHAPTER

1

Introduction

1.1 History

The most widely felt earthquakes in the recorded history of North America were a series that occurred in 1811-1812 near New Madrid, Missouri. A great earthquake, whose magnitude is estimated to be about 8, occurred on the morning of December 16, 1811 [1].

The 1934 Bihar earthquake is considered to be one of the worst quakes in Indian history. The quake occurred on January 15, 1934 and was recorded 8.1 on the Richter scale. Over 30,000 people were said to have been killed in the disaster. The epicenter of the earthquake was located in eastern Nepal [2].

In 1923, a magnitude 7.9 earthquake struck the Kanto plain on the island of Honshu on the morning of Sept. 1. The shaking lasted up to 10 minutes in some places. The quake devastated Tokyo, then home to about 2 million people, and caused widespread damage throughout the Kanto region [3].

The 2001 Gujarat earthquake also known as Bhuj earthquake occurred on 26 January, India's 52nd Republic Day, at 08:46 AM IST and lasted for over 2 minutes. The epicenter was about 9 km south-southwest of the village of Chobari in Bhachau Taluka of Kutch District of Gujarat, India [4].

The highest earthquake magnitude experienced in Delhi in about a century was on July 27, 1960. It registered 5.6 on the Richter scale. Some buildings in

New Delhi area were partially damaged during that quake. A seismic damage survey, by the Central Public Works Department (CPWD), put the damage at about Rs 0.5 million [5].

A 6.5 magnitude earthquake struck the Indonesian island of Sumatra. According to the US Geological Survey, the epicenter of the powerful earthquake was located approximately 25 miles from the coast. Tremors of the earthquake were felt as far away as Singapore [6].

FIGURE 1.1 Earthquakes in Indonesia [7]

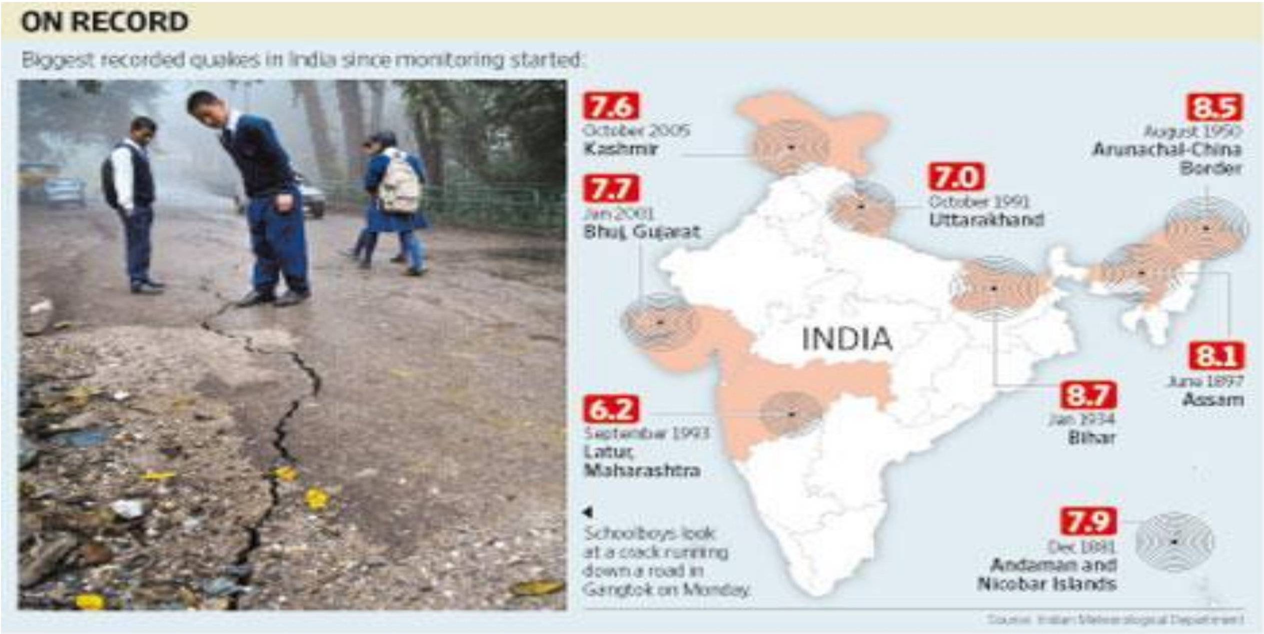

FIGURE 1.2 Different Earthquake Zones in India [8]

1.2 Development of earthquake measuring instruments

Although we still cannot accurately predict earthquakes, we have come a long way in detecting, recording, and measuring seismic shocks. Many don't realize that this process began nearly 2000 years ago, with the invention of the first seismoscope in 132 AD by a Chinese inventor called Zhang ('Chang') Heng. The device was remarkably accurate in detecting earthquakes from afar, and did not rely on shaking or movement in the location where the device was situated.

The ancient Chinese did not understand that earthquakes were caused by the shifting of tectonic plates in the Earth's crust; instead, the people explained them as disturbances with cosmic yin and yang, along with the heavens' displeasure with acts committed (or the common peoples' grievances ignored) by the current ruling dynasty. Considering the ancient Chinese believed seismic events were important signs from heaven, it was important for the Chinese leaders to be alerted to earthquakes occurring anywhere in their kingdom.

Zhang Cheng was an astronomer, mathematician, engineer, geographer and inventor, who lived during the Han Dynasty (25 – 220 AD). He is credited with developing the world's first earthquake detector. Zhang's seismoscope was a giant bronze vessel, resembling a samovar almost 6 feet in diameter. Eight dragons snaked face-down along the outside of the barrel, marking the primary compass directions. In each dragon's mouth was a small bronze ball.

Beneath the dragons sat eight bronze toads, with their broad mouths gaping to receive the balls.

The exact mechanism that caused a ball to drop in the event of an earthquake is still unknown. One theory is that a thin stick was set loosely down the centre of the barrel. An earthquake would cause the stick to topple over in the direction of the seismic shock, triggering one of the dragons to open its mouth and release the bronze ball. The sound of the ball striking one of the eight toads would alert observers to the earthquake and would give a rough indication of the earthquake's direction of origin.

In 138 AD, the sound of the bronze ball dropping caused a stir among all the imperial officials in the palace. No one believed that the invention actually worked. According to the direction in which the dragon that dropped the ball was oriented, it was determined that the quake had occurred to the west of Luoyang, the capital city. Since no one had sensed anything in Luoyang proper, people were sceptical. However, a few days later, a messenger from the western Long region (today, southwest Gansu province), which was west of Luoyang, reported that there had been an earthquake there. As it happened exactly the same time that the seismometer was triggered, people were greatly impressed by Zhang Heng’s instrument.

In 2005, scientists in Zengzhou, China (which was also Zhang's hometown) managed to replicate Zhang's seismoscope and used it to detect simulated earthquakes based on waves from four different real-life earthquakes in China and Vietnam. The seismoscope detected all of them. As a matter of fact, the data gathered from the tests corresponded accurately with that gathered by modern-day seismometers!

Today, from an advanced modern science and technology point of view, the seismometer Zhang Heng invented is still considered amazingly refined and remarkable and way ahead of its time. [9]

The Richter scale was developed in 1935 by American seismologist Charles Richter (1891-1989) as a way of quantifying the magnitude, or strength, of earthquakes. Richter, who was studying earthquakes in California at the time, needed a simple way to precisely express what is qualitatively obvious: some earthquakes are small and others are large.

An earthquake is a violent shaking of the ground that is usually caused by sudden motion on a geological fault. For example, the magnitude 6.9 1994 Northridge earthquake, which resulted in severe damage in the Los Angeles, area, was caused by between two and four meters of slip on a fault measuring about 12 kilometers long and 15 kilometers wide, 10

kilometers beneath the city's northern suburbs. Today, earthquakes and fault motion are inextricably linked in the minds of seismologists--so much so that upon hearing that an earthquake has occurred, we immediately ask about the fault that caused it. Richter's focus, in contrast, was on the ground vibration itself, which he could easily monitor using seismometers at the California Institute of Technology (Caltech). To Richter, a high-magnitude earthquake was one with strong ground vibration. Thus, for the Richter scale no direct connection is made to any of the properties of the causative fault.

Richter's scale was modeled on the stellar magnitude scale used by astronomers, which quantifies the amount of light emitted by stars (their luminosity). A star's luminosity is based on telescopic observations of its brightness that are corrected for the telescope's magnification and for the star's distance from Earth. But because luminosity varies over many factors of ten (Betelgeuse is 50,000 times more luminous than Alpha Centauri, for example), astronomers calculate a logarithm of the luminosity to produce the stellar magnitude: an easy-to-remember single-digit number.

Richter substituted measurements of the amount of ground vibration, as measured by a seismograph, for measurements of luminosity. Note that in both cases the sense of strength is quite abstract: stellar magnitude is not a measure of the physical size of a star (as might be quantified by its diameter), but rather of the amount of light that the star emits. Seismic magnitude is not a measure of the physical size of the earthquake fault (as might be quantified by its area or its slip) but rather of the amount of vibration that it emits.

In Richter's initial formulation, an earthquake 100 kilometers away that caused a one-millimeter amplitude signal on the Caltech seismometer's paper recorder was arbitrarily defined to be magnitude 3. (The magnification of Richter's seismometer was about 2,800, so one millimeter on the paper record corresponds to about 0.36 microns of actual ground motion). An earthquake at the same distance that produced a 10-millimeter amplitude recording was designated magnitude 4, a 100-millimeter amplitude was magnitude 5, and so forth. Richter then went on to devise correction tables that allowed magnitudes to be calculated regardless of the actual distance of the earthquake from the seismometer.

The appeal of the Richter magnitude scale is twofold. First, an earthquake is summarized by an easy-to-remember and easy-to-interpret single-digit number. A magnitude 3 is a tiny earthquake. A magnitude 6 is one that can cause substantial damage. A magnitude 9, like the one that caused December's deadly Indian Ocean tsunami, is capable of causing severe devastation. Second, the magnitude can easily be determined from measurements made by a seismometer, which need not be located particularly close to the fault. Indeed, modern

seismometers can record earthquakes of magnitude 5 and above occurring anywhere in the world. The downside to the Richter scale is that magnitude is a single number, which cannot fully characterize a complicated phenomenon such as an earthquake. Earthquakes with the same magnitude can differ in many fundamental ways, including the directions of the vibrations, and their relative amplitude at different periods during the tremble. These differences can lead to earthquakes with the same magnitude having significantly different levels of destructiveness.

Beginning in the mid-1960's, seismologists developed a fairly complete understanding of how a slipping fault generates ground vibrations. An important quantity that characterizes the strength of the faulting is the seismic moment, the algebraic product of the fault area, the fault slip and the stiffness of the surrounding rock. Generally speaking, an earthquake with large magnitude corresponds to faulting with a large moment, with an increase in one magnitude unit corresponding to an increase of moment by about a factor of 30. But the relationship is inexact, and many cases occur where small faulting causes an unexpectedly large magnitude earthquake or vice versa [10].

FIGURE 1.3 Ancient Earthquake Detector [11].

The seismograph was made of fine copper, and was an urn-like instrument with a central pendulum. The instrument was cast with eight dragons on the surface (whose heads pointed in eight directions -east, south, west, north, southeast, northeast, southwest, and northwest), each one holding a copper ball in its mouth. Below the dragons were eight copper toads raising their heads and opening their mouths opposite the dragons' mouths. The inner side of the seismograph was ingeniously constructed: when an earthquake occurred, an earth tremor

would cause the pendulum to lose balance and activate a set of levers inside. Then, one of the eight dragons outside the urn would release the bronze ball held in its mouth. The ball would fall into the mouth of the toad and give off a sound, letting people know when and in which direction an earthquake had occurred. The seismograph was one of the most brilliant achievements in the history of Ancient China. It was invented in 132 AD, by a man known as Zhang Heng. This way, the Ancient Chinese could tell which way the earthquake came from, by simply checking which toad had the ball in its mouth. They could also nearly pinpoint where the earthquake started by having seismographs at strategic point all-over China.

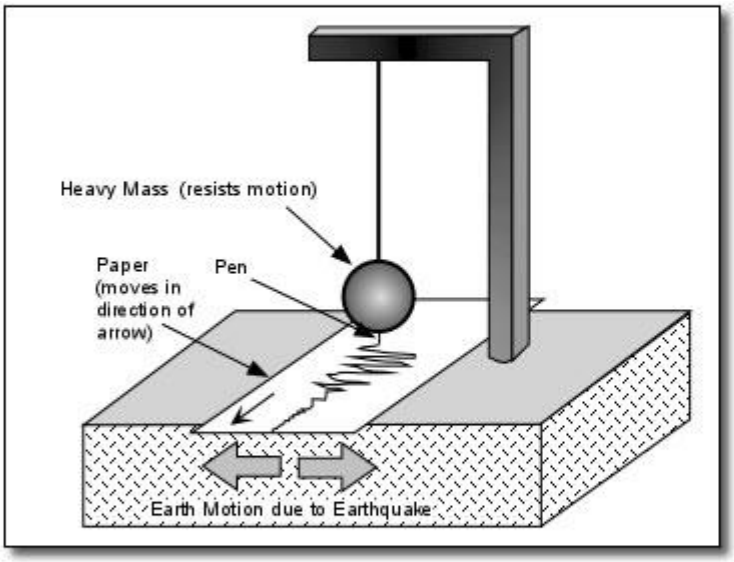

FIGURE 1.4 Pendulum Seismometer [12]

A simple seismometer that is sensitive to horizontal motions of the earth can be understood by visualizing a weight hanging on a spring. The spring and weight are suspended from a frame that moves along with the earth's surface. As the earth moves, the relative motion between the weight and the earth provides a measure of the vertical ground motion. If a recording system is installed, such as a rotating graph attached to the frame, and a pen attached to the mass, this relative motion between the weight and earth can be recorded to produce a history of ground motion, called a seismogram. Any movement of the ground moves the frame. The mass tends not to move because of its inertia, and by measuring the movement between the frame and the mass, the motion of the ground can be determined.

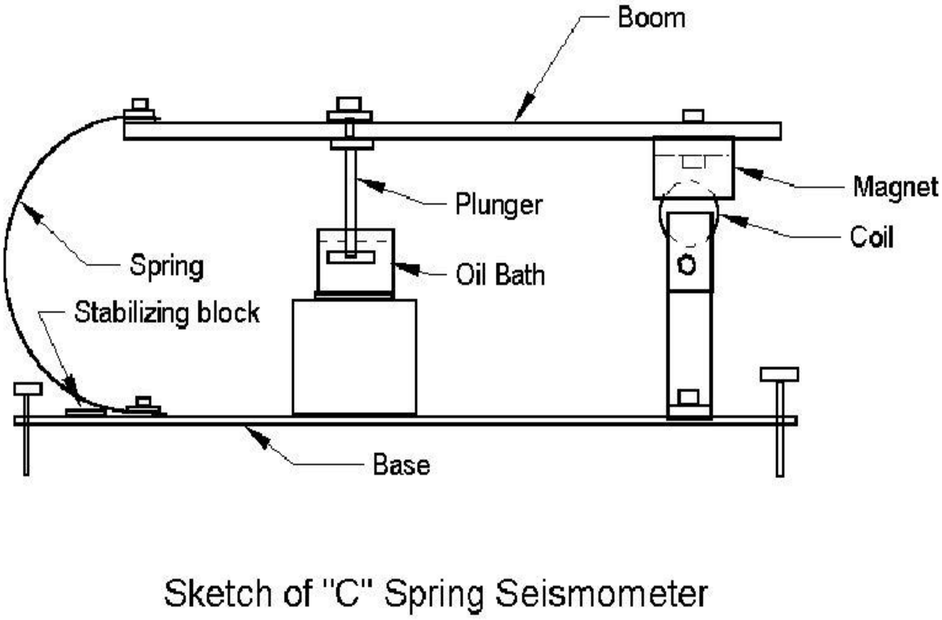

FIGURE 1.5 Spring Seismometer [13]

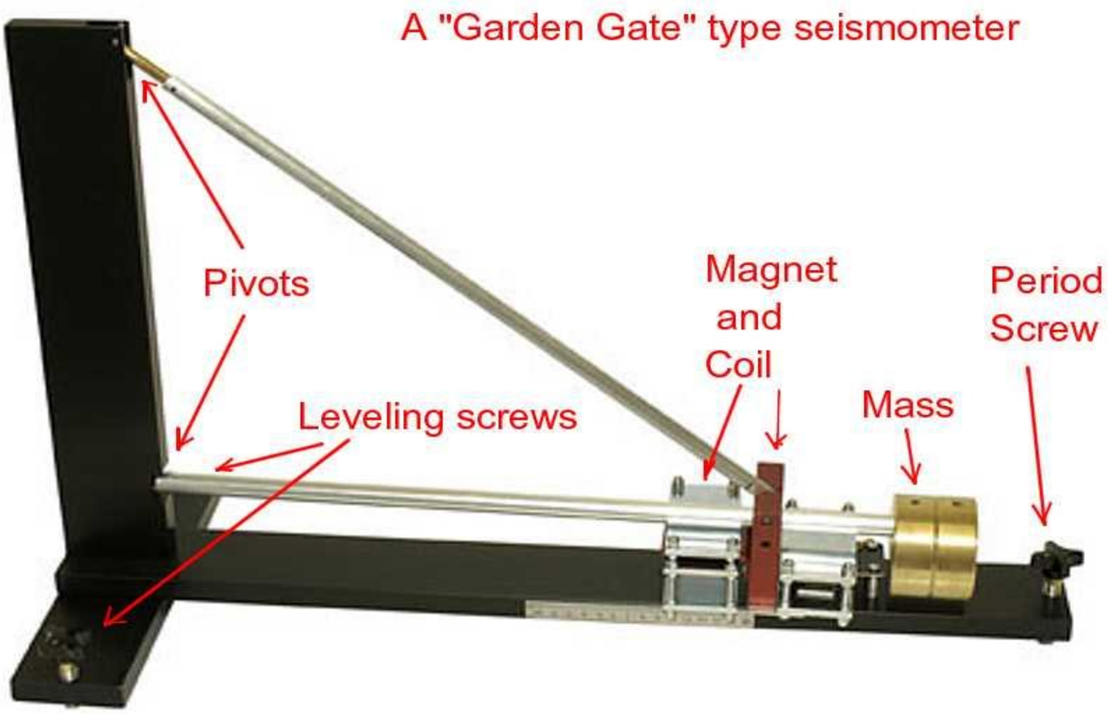

FIGURE 1.6 Garden Gate Type Seismometer [14]

CHAPTER

2

Earthquake

2.1 Earthquake Classification

TABLE 1 [15]

MAGNITUDE	CLASSIFICATION
$M \geq 8.0$	Great Earthquake
$7 \leq M < 8.0$	Major / Large Earthquake
$5.0 \leq M < 7.0$	Strong Earthquake
$3.0 \leq M < 5.0$	Small Earthquake
$1.0 \leq M < 3.0$	Micro earthquake
$M < 1.0$	Ultra Micro earthquake

2.2 Nature of Earthquakes

1) Foreshocks
2) Main shock
3) Aftershocks
4) Earthquake Swarm

2.3 Types of Earthquakes

1) Tectonic Earthquake
2) Volcanic Earthquake
3) Collapse Earthquake
4) Explosion Earthquake

2.4 Theory

Seismic waves are waves of energy that travel through the Earth's layers, and are a result of earthquakes, volcanic eruptions, magma movement, large landslides and large man-made explosions that give out low-frequency acoustic energy. Many other natural and anthropogenic sources create low-amplitude waves commonly referred to as ambient vibrations. Seismic waves are studied by geophysicists called seismologists. Seismic wave fields are recorded by a seismometer, hydrophone (in water), or accelerometer.

The propagation velocity of the waves depends on density and elasticity of the medium. Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deep mantle.

Earthquakes create distinct types of waves with different velocities; when reaching seismic observatories, their different travel times help scientists to locate the source of the hypocenter. In geophysics the refraction or reflection of seismic waves is used for research into the structure of the Earth's interior, and man-made vibrations are often generated to investigate shallow, subsurface structures.

2.4.1 Types

Among the many types of seismic waves, one can make a broad distinction between body waves and surface waves.

- Body waves travel through the interior of the Earth.
- Surface waves travel across the surface. Surface waves decay more slowly with distance than do body waves, which travel in three dimensions.
- Particle motion of surface waves is larger than that of body waves, so surface waves tend to cause more damage [15].

Body Waves:

Body waves travel through the interior of the Earth. They create ray paths refracted by the varying density and modulus (stiffness) of the Earth's interior. The density and modulus, in turn, vary according to temperature, composition, and phase. This effect resembles the refraction of light waves, includes Primary and Secondary waves.

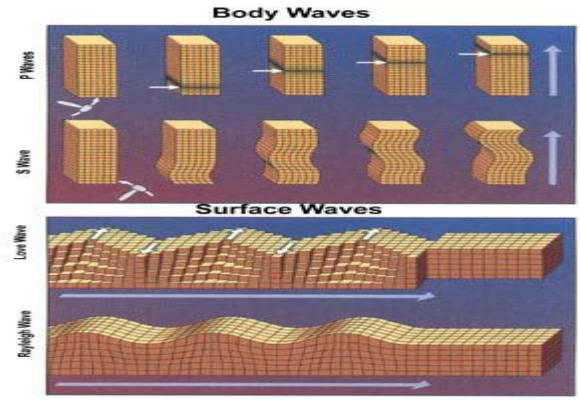

FIGURE 2.1 Different types of earthquake waves [16]

Primary waves:

Primary waves (P-waves) are compression waves that are longitudinal in nature. P waves are pressure waves that travel faster than other waves through the earth to arrive at seismograph stations firstly, hence the name "Primary". These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves. In air, they take the form of sound waves, hence they travel at the speed of sound. Typical speeds are 330 m/s in air, 1450 m/s in water and about 5000 m/s in granite.

Secondary waves:

Secondary waves (S-waves) are shear waves that are transverse in nature. Following an earthquake event, S-waves arrive at seismograph stations after the faster-moving P-waves and displace the ground perpendicular to the direction of propagation. Depending on the propagation direction, the wave can take on different surface characteristics; for example, in the case of horizontally polarized S waves, the ground moves alternately to one side and then the other. S-waves can travel only through solids, as fluids (liquids and gases) do not support

shear stresses. S-waves are slower than P-waves, and speeds are typically around 60% of that of P-waves in any given material.

Surface waves:

Seismic surface waves travel along the Earth's surface. They can be classified as a form of mechanical surface waves. They are called surface waves, as they diminish as they get further from the surface. They travel more slowly than seismic body waves (P and S). In large earthquakes, surface waves can have amplitude of several centimeters.

Rayleigh waves:

Rayleigh waves, also called ground roll, are surface waves that travel as ripples with motions that are similar to those of waves on the surface of water (note, however, that the associated particle motion at shallow depths is retrograde, and that the restoring force in Rayleigh and in other seismic waves is elastic, not gravitational as for water waves). The existence of these waves was predicted by John William Strut, Lord Rayleigh, in 1885. They are slower than body waves, roughly 90% of the velocity of S waves for typical homogeneous elastic media. In the layered medium (like the crust and upper mantle) the velocity of the Rayleigh waves depends on their frequency and wavelength. See also Lamb waves.

Love waves:

Love waves are horizontally polarized shear waves (SH waves), existing only in the presence of a semi-infinite medium overlain by an upper layer of finite thickness. They are named after A.E.H. Love, a British mathematician who created a mathematical model of the waves in 1911. They usually travel slightly faster than Rayleigh waves, about 90% of the S wave velocity, and have the largest amplitude.

Stoneley waves:

A Stoneley wave is a type of boundary wave (or interface wave) that propagates along a solid-fluid boundary or, under specific conditions, also along a solid-solid boundary. Amplitudes of Stoneley waves have their maximum values at the boundary between the two contacting media and decay exponentially towards the depth of each of them. These waves

can be generated along the walls of a fluid-filled borehole, being an important source of coherent noise in VSPs and making up the low frequency component of the source in sonic logging. The equation for Stoneley waves was first given by Dr. Robert Stoneley (1894 - 1976), Emeritus Professor of Seismology, Cambridge.

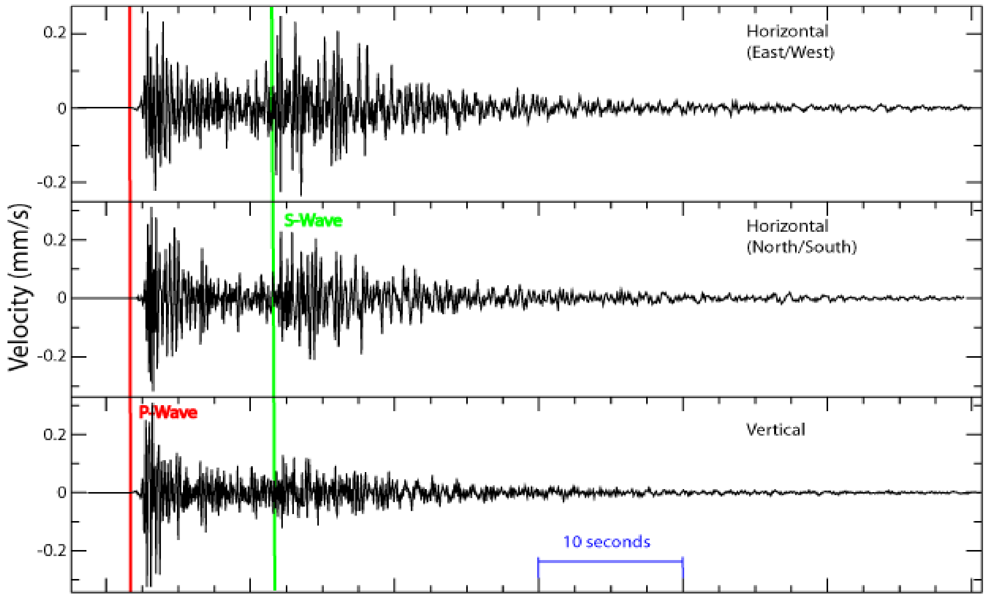

FIGURE 2.2 Velocity-Time Graph of earthquake waves

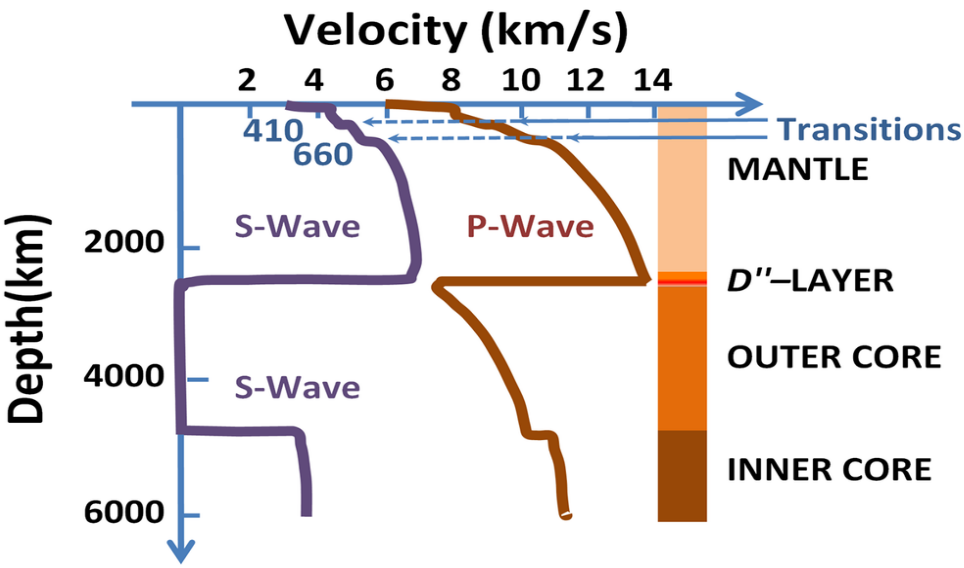

FIGURE 2.3 Velocity-Depth Graph of Earthquake Waves [17]

CHAPTER

3

Construction

The earthquake vibration measuring instrument consists of various components. They are as follows:

1. Rectangular Slab.
2. Springs.
3. Roller Bearings.
4. Infra Red Sensor.
5. Motion Transmitting Mechanism and Piston Cylinder Stamping Pad Arrangement.
6. Assembly.

3.1 Rectangular Slab

The rectangular slab is the metallic body which experiences the main force of earthquake vibrations. This rectangular slab moves to and fro due to inertia effect. This rectangular slab rests on the base with the help of four roller bearings.

Initially we had 6 plates of different dimensions. Dimensions of plates are as follows:

2 plates of 16.5 × 9 cm

2 plates of 9 × 7.5 cm

2 plates of 16.5 ×7.5 cm

Arc welding (Shielded Metal Arc Welding) is used to join these 6 plates to each other. Joints are made in such a way that finally a rectangular slab is obtained.

Total mass of the rectangular slab is 2.160 kg. 4 hooks are also welded to the two side faces of the slab. These hooks are used to hang springs in them.

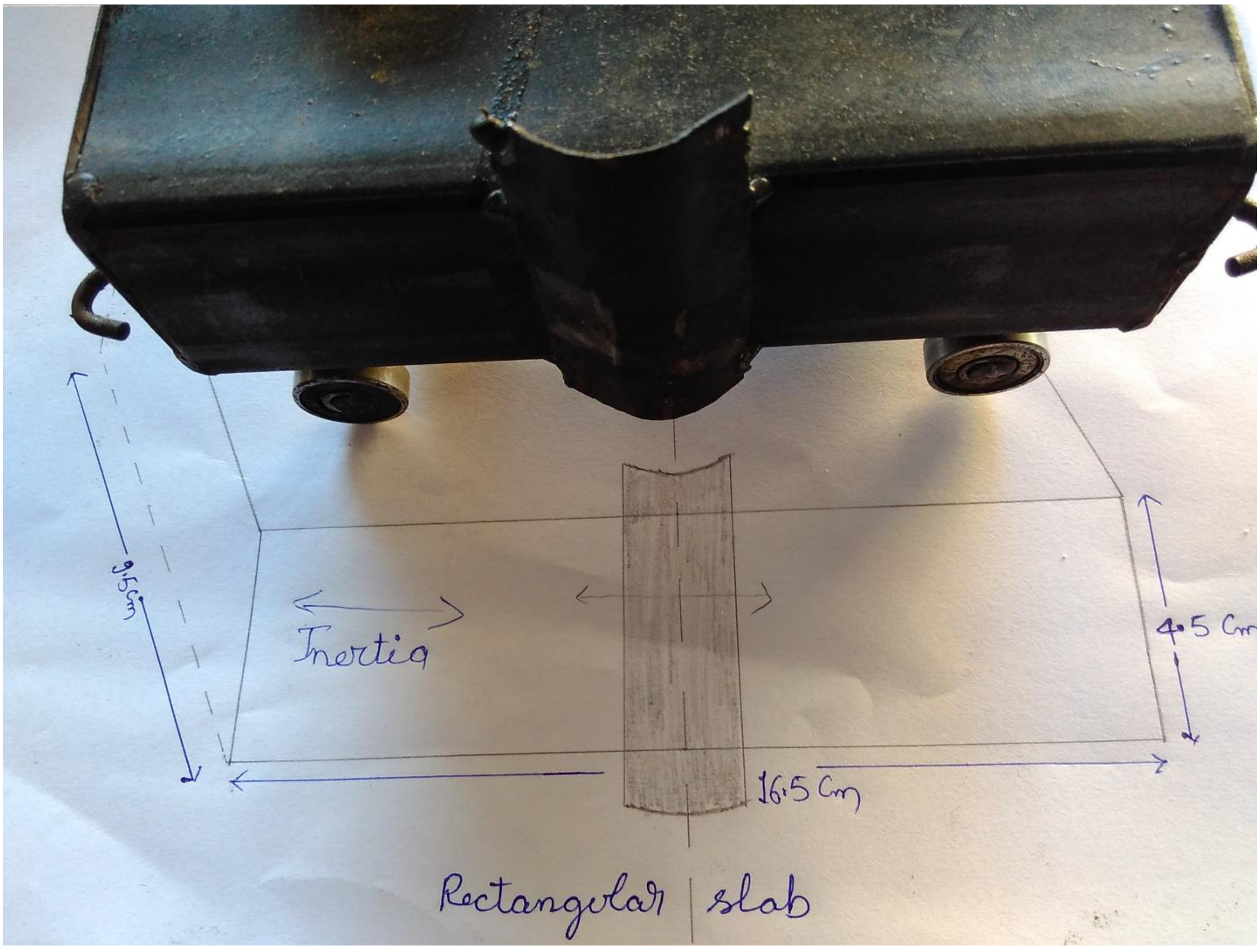

FIGURE 3.1 Rectangular Slab

3.2 Springs

Helical springs are attached to the slab with the help of hooks. One end of springs are connected to the hooks and the other ends of springs are connected to the vertical columns of the base.

Functions of springs in this system:

1. To store energy for part of a functioning cycle.
2. To counterbalance a weight or thrust (inertial). Such springs are known as equilibrator springs.
3. To return a component to its original position after displacement.

These springs are made up of high carbon steel.
Length of spring in unstretched condition: 12 cm.
Length of spring in stretched condition: 20 cm.
Diameter of spring: 1.8 cm.
Diameter of wire: 1.3 mm.
Total no. of springs: 4

FIGURE 3.2 Springs

3.3 Roller Bearings

Bearings are highly engineered, precision-made components that enable machinery to move at extremely high speeds and carry remarkable loads with ease and efficiency. Bearings must be able to offer high precision, reliability and durability, as well as the ability to rotate at high speeds with minimal noise and vibration ,Bearings are found in applications ranging from automobiles, airplanes, computers, construction equipment, machine tools, DVD players, refrigerators and ceiling fans. If something twists, turns or moves, it probably has a bearing in it.

Its cage less, but a ball is a non-contact ideal figure.) A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads.
Bearings used in this system:
6000-Z Deep groove ball bearings single row Radial Bearing 10 mm ID x 26 mm OD x 8 mm wide.

Outer Diameter (OD): 26 mm

Size: 10×26×8 mm

These bearings are made up of chrome steel.

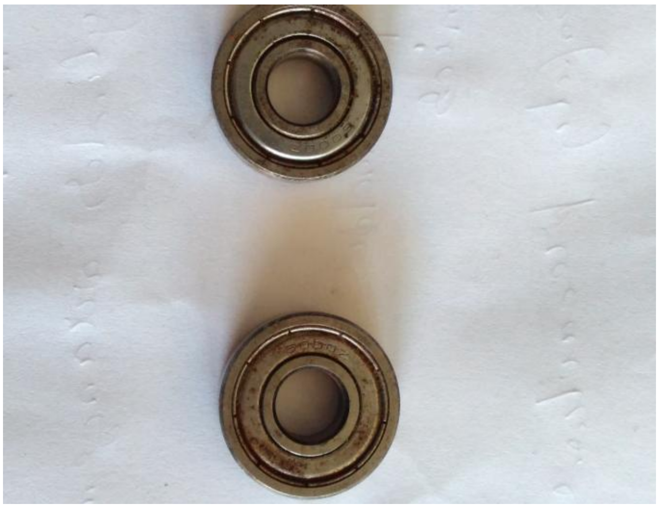

FIGURE 3.3 Roller Bearings

3.4 Infra Red Sensor

The sensor used in this instrument is Infra Red sensor. Basically this sensor consists of a transmitter and a receiver. A passive infra red sensor is an electronic sensor that measures infra red light radiating from the objects in its field of view. The PIR sensor is typically mounted on a printed circuit board containing the necessary electronics required to interpret the signals from the sensor itself. The complete assembly is usually contained within housing, mounted in a location where the sensor can cover area to be monitored.

The housing will usually have a plastic "window" through which the infrared energy can enter. Despite often being only translucent to visible light, infrared energy is able to reach the sensor through the window because the plastic used is transparent to infrared radiation. The plastic window reduces the chance of foreign objects (dust, insects, etc.) from obscuring the sensor's field of view, damaging the mechanism, and/or causing false alarms. The window may be used as a filter, to limit the wavelengths to 8-14 micrometers, which is closest to the infrared radiation emitted by humans.

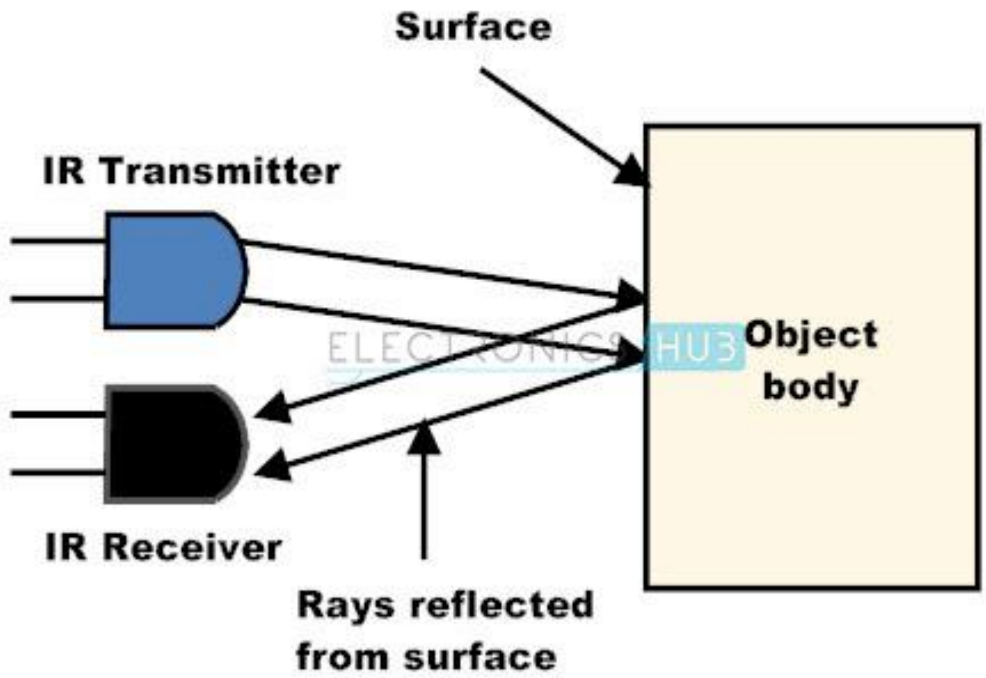

FIGURE 3.4 Infra Red Sensor Basics

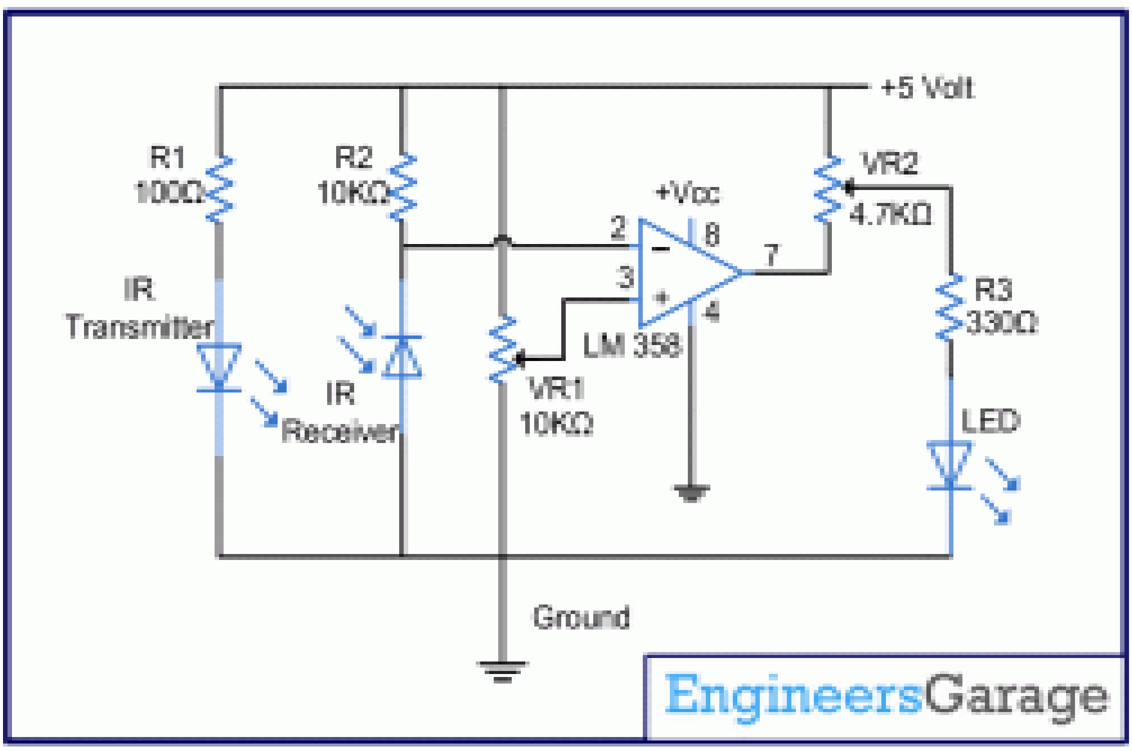

FIGURE 3.5 Infra Red Sensor Circuit

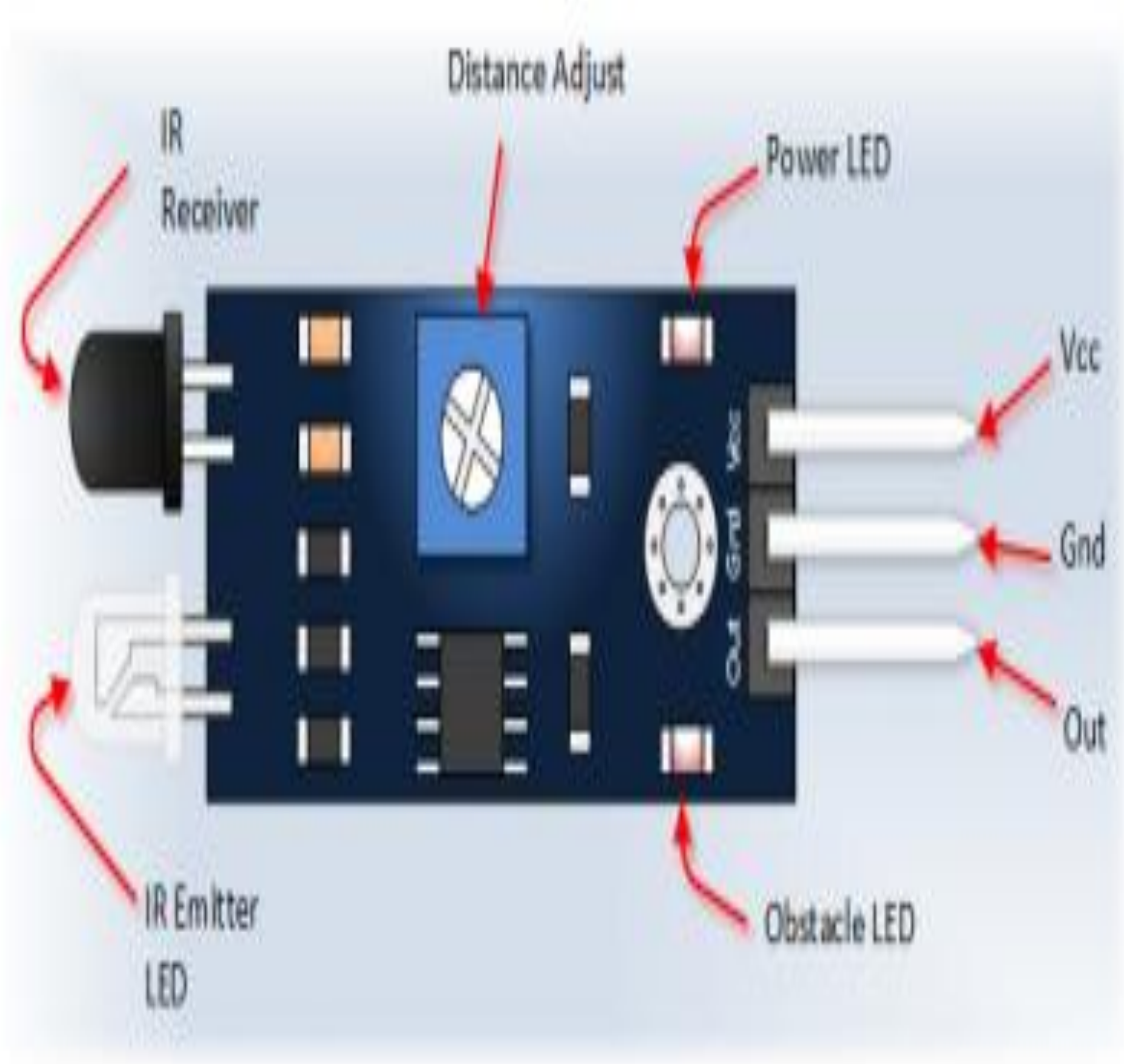

FIGURE 3.6 Infra Red Sensor [18]

3.5 Motion Transmitting Arrangement and Piston Cylinder Stamping Pad Arrangement

This mechanism is used to transmit motion from moving rectangular slab to the piston and piston head act as stamping pad. Spiral coil move around the main rod smoothly and to retrieve mechanism in previous position we use counterbalance weight and it hold the mechanism on motion dead line.

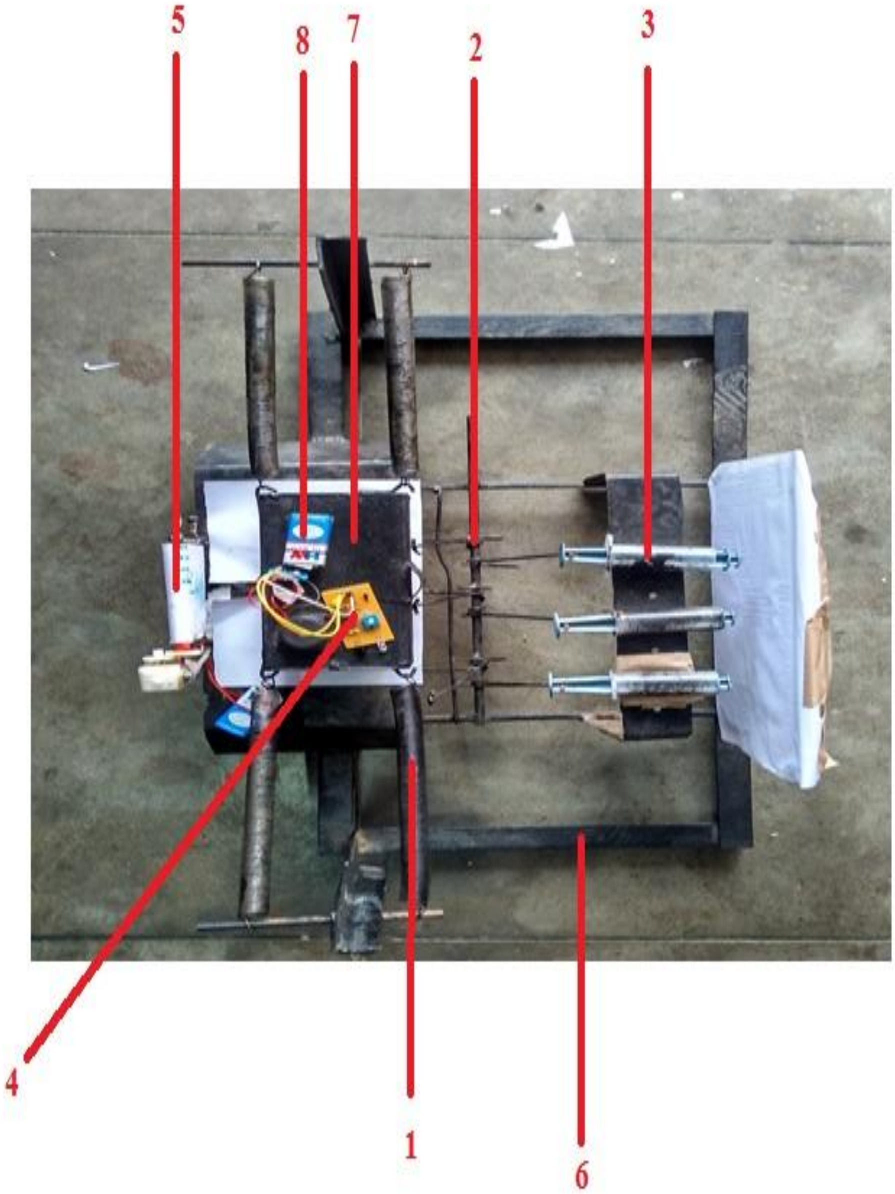

FIGURE 3.7 Whole Assembly of Model

1. Spring
2. Motion transmitting mechanism
3. Piston-Cylinder
4. IR Sensor
5. Graph Paper
6. Frame
7. Movable slab
8. Battery

3.6 Assembly

- First we construct a frame of dimension 60×30 centimeter.
- We welded a rectangular plate of cast iron having dimension of 30×15 at the base.
- Then we welded two vertical columns on the frame for spring support.
- We also welded piston support on the frame.
- A vertical rectangular plate also welded on the frame for stamp of piston.
- Then we construct a mechanism with the help of link which transfer the reciprocating motion of slab to the pistons.
- We attached the infrared sensor on the top of the rectangular slab.
- We also welded a vertical support on the frame for the graph.
- We welded the bearings to this slab for the translator motion.
- We made a parallel arrangement of spring by attaching their one end at the slab and the other to the vertical column.

CHAPTER

4

Working

4.1 Process

As earthquake wave hit the rectangular slab then due to inertia effect rectangular slab try to remain in rest position and due to the earthquake whole base structure with spring move in direction of wave so that there is a relative motion in rectangular slab with respect to base neutral axis and due to motion of slab-attached motion transmitting mechanism come into action. if low magnitude earthquake occur then low amplitude wave hit the slab, and slab travel small distance about neutral axis due to which closest mechanism to the neutral axis come into action so that spiral coil move around the primary base rod and forward link transmit the motion to piston cylinder assembly and piston head act as stamping pad and hit the numbering plate after that counterbalance weight bring back the mechanism in previous state .if large amplitude wave hit the slab then second closest mechanism come into action and work like previous one again if more big wave hit more furthest mechanism work similarly by this way measuring instrument work.

Due to motion of slab infrared sensor come into action because this sensor attached with slab at neutral position and there is black rectangular strip attached with base plate at neutral position when these two coincide then light emitting by transmitter LED is absorb by the black strip and receiver LED could not receive any light so circuit does not complete and

alarm does not beep ,after moving of sensor about neutral axis it come across white area where transmitter transmit the light and white color reflect this light to the receiver by this way basic circuit completed and alarm beep.

Process Parameters

4.2.1 Magnitude and Intensity

Intensity:

- How Strong Earthquake Feels to Observer
- Qualitative assessment of the kinds of damage done by an earthquake
- Depends on distance to earthquake & strength of earthquake
- Determined from the intensity of shaking and damage from the earthquake

The Modified Mercalli Scale of Earthquake Intensity:
In seismology a scale of seismic intensity is a way of measuring or rating the effects of an earthquake at different sites. The Modified Mercalli Intensity Scale is commonly used in the United States by seismologists seeking information on the severity of earthquake effects. Intensity ratings are expressed as Roman numerals between I at the low end and XII at the high end.

The Intensity Scale differs from the Richter Magnitude Scale in that the effects of any one earthquake vary greatly from place to place, so there may be many Intensity values measured from one earthquake. Each earthquake, on the other hand, should have just one Magnitude, although the several methods of estimating it will yield slightly different values.

Ratings of earthquake effects are based on the following relatively subjective scale of descriptions:

Modified Mercalli Intensity Scale:
I. People do not feel any Earth movement.

II. A few people might notice movement if they are at rest and/or on the upper floors of tall buildings.

III. Many people indoors feel movement. Hanging objects swing back and forth. People outdo IV. Most people indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. The earthquake feels like a heavy truck hitting the walls. A few people outdoors may feel movement. Parked cars rock.

V. Almost everyone feels movement. Sleeping people are awakened. Doors swing open or close. Dishes are broken. Pictures on the wall move. Small objects move or are turned over. Trees might shake. Liquids might spill out of open containers.

VI. Everyone feels movement. People have trouble walking. Objects fall from shelves. Pictures fall off walls. Furniture moves. Plaster in walls might crack. Trees and bushes shake. Damage is slight in poorly built buildings. No structural damage.

VII. People have difficulty standing. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Damage is slight to moderate in well-built buildings; considerable in poorly built buildings.

VIII. Drivers have trouble steering. Houses that are not bolted down shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Well-built buildings suffer slight damage. Poorly built structures suffer severe damage. Tree branches break. Hillsides might crack if the ground is wet. Water levels in wells might change.

IX. Well-built buildings suffer considerable damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks. Reservoirs suffer serious damage.

X. Most buildings and their foundations are destroyed. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, lakes. The ground cracks in large areas. Railroad tracks are bent slightly.

XI. Most buildings collapse. Some bridges are destroyed. Large cracks appear in the ground. Underground pipelines are destroyed. Railroad tracks are badly bent.

XII. Almost everything is destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.

As you can see from the list above, rating the Intensity of an earthquake's effects does not require any instrumental measurements. Thus seismologists can use newspaper accounts, diaries, and other historical records to make intensity ratings of past earthquakes, for which

there are no instrumental recordings. Such research helps promote our understanding of the earthquake history of a region, and estimate future hazards.

Magnitude:

Related to Energy Release,

- Quantitative measurement of the amount of energy released by an earthquake
- Depends on the size of the fault that breaks
- Determined from Seismic Records

The familiar Richter scale (which is not a physical device but rather a mathematical formula) is no longer widely used by scientists or the media to report an earthquake's size.

Today, an earthquake's size is typically reported simply by its magnitude, which is a measure of the size of the earthquake's source, where the ground began shaking.

While there are many modern scales used to calculate the magnitude, the most common is the moment magnitude, which allows for more precise measurements of large earthquakes than the Richter scale.

In the news, however, when an earthquake's magnitude is given , the scale used to calculate the magnitude is not usually specified since the modern scales are all very similar.

A network of geological monitoring stations, each with instruments that measure how much the ground shakes over time called seismographs allow scientists to calculate an earthquake's time, location and magnitude.

Seismographs record a zigzag trace that shows how the ground shakes beneath the instrument. Sensitive seismographs, which greatly magnify these ground motions, can detect strong earthquakes from sources anywhere in the world.

From these measurements, a quake's magnitude is usually reported as, for example, a magnitude-7.0 in the case of the earthquake that struck Haiti on Jan. 12.

Based on their magnitude, quakes are assigned to a class, according to the U.S. Geological Survey. An increase in one number, say from 5.5 to 6.5, means that a quake's magnitude is 10 times as great. The classes are as follows:

- Great*:* Magnitude is greater than or equal to 8.0. A magnitude-8.0 earthquake is capable of tremendous damage.

- Major*:* Magnitude in the range of 7.0 to 7.9. A magnitude-7.0 earthquake is a major earthquake that is capable of widespread, heavy damage.
- Strong*:* Magnitude in the range of 6.0 to 6.9. A magnitude-6.0 quake can cause severe damage.
- Moderate*:* Magnitude in the range of 5.0 to 5.9. A magnitude-5.0 quake can cause considerable damage.
- Light*:* Magnitude in the range of 4.0 to 4.9. A magnitude-4.0 quake is capable of moderate damage.
- Minor*:* Magnitude in the range of 3.0 to 3.9.
- Micro*:* Magnitude less than-3.0. Quakes between 2.5 and 3.0 are the smallest generally felt by people.

Details of earthquake alarming and measuring system:

Mass of rectangular slab (Ms) = 2.160 kg.

No. of roller bearings= 4

1 motion sensor

No. of springs=4

Piston Cylinder Assemblies= 3

Initial length of spring (Xi) = 12 cm.

Final length of spring (Xo) = 20 cm.

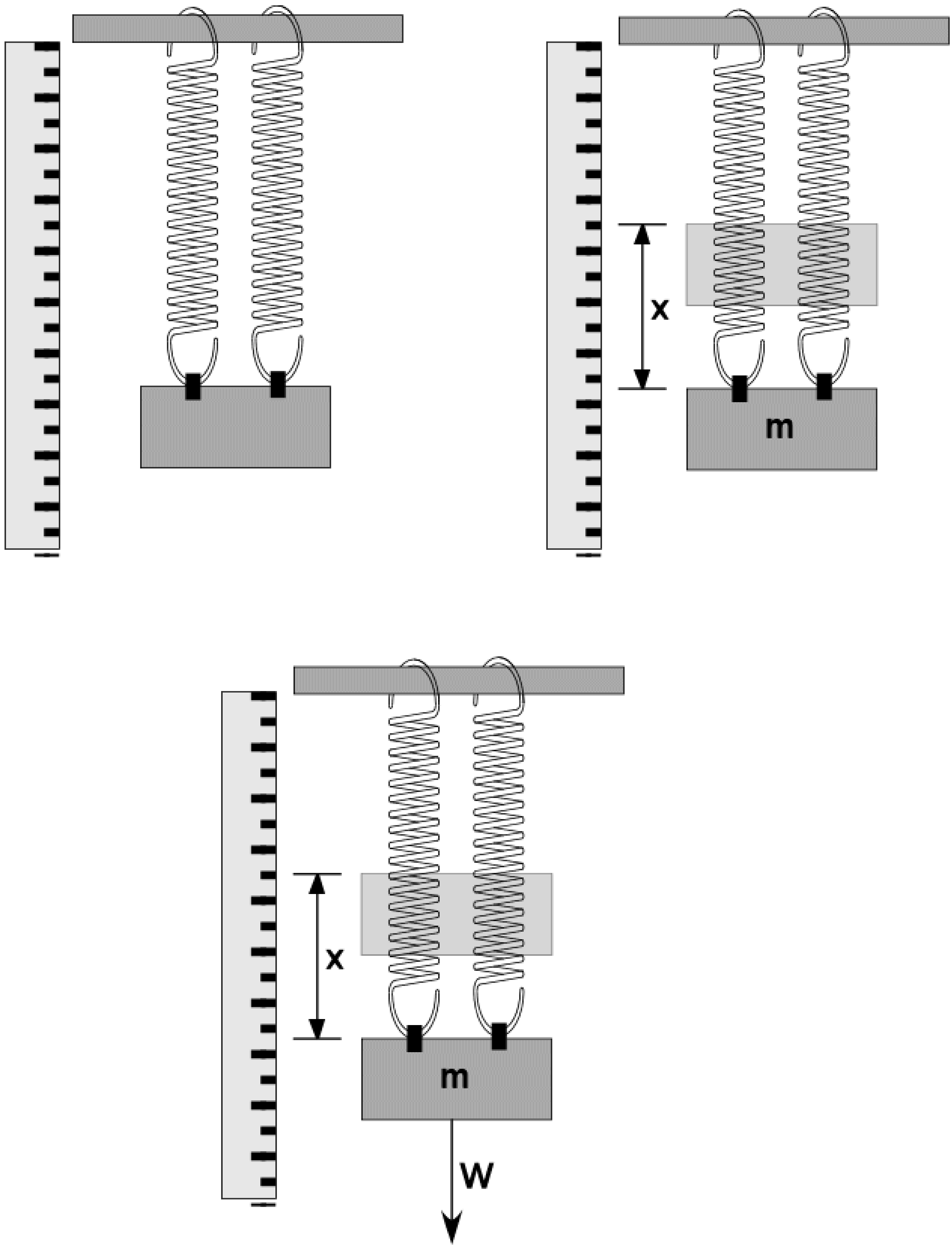

FIGURE 4.1. Vertically suspended spring-mass system [19]

According to Hook's law: Hooke's law is a principle of physics that states that the force F needed to extend or compress a spring by some distance X is proportional to that distance. That is: F = kX, where k is a constant factor characteristic of the spring: its stiffness, and *X* is small compared to the total possible deformation of the spring.

$F = M_s \times g.$

$= 2.160 \times 9.81$

$= 21.18$ N.

Deflection in the spring ($X_o - X_i = dx$) = 20 -12 = 8 cm.

Equivalent stiffness of the system:

$K_{eq} = k + k$

$= 2k$

$K_{eq} = (Ms \times g)/dx$

$= 132.435$ N/m.

Distance between 1st & 2nd scale = 3 cm.

Distance between 1st & 3rd scale = 7 cm

Distance between 2nd & 3rd scale = 10 cm

Distance between neutral axis & 1st scale Xs^1 = 1 cm

Distance between neutral axis & 2nd scale Xs^2 = 4 cm

Distance between neutral axis & 3rd scale Xs^3 = 6 cm

Length of spring in arrangement= 13 cm.

Height of spring from parallel base= 6 cm.

Spring inclination: Ø

Sin Ø= 6/13= 0.462.

Ø= 27.48

Cos Ø= 0.88

Force required for hitting the first scale:

$F1 = 4K\cos Ø \times Xs^1$

$= 4.66$ N

Force required for hitting the second scale:

$F2 = 4K\cos Ø \times Xs^2$

$= 18.65$ N

Force required for hitting the third scale:

$F3 = 4K\cos Ø \times Xs = 27.98$ N

4.2.2 Friction between base plate and ball bearings:

Experimentally calculated values:

Force applied on the system:

$F_a = 13.24$ N

$M_s = 2.160$ kg.

g = 9.81.

K = 132.435 N/m.

X = 0.05 m.

Cos Ø= 0.88

According to D' Alembert's Principle:

$F_a + (\mu \times M_s \times g) = 4KX\cos Ø.$

$13.24 + 21.18\mu = 23.5.$

$\mu = 0.484.$

4.2.3 Kinetic energy of spring having mass:

Mass of spring = m_s, Total length of the spring after extension = L

Velocity of the spring at the distance L = V

So, the velocity of the spring at distance y will be = (V/L) × y

Mass of the small element of the spring dm= $(m_s/L) \times dy$

Kinetic energy of this element = ½ × mass of element × (velocity of this element)²

$$= \frac{1}{2} (m_s/L \times dy)(V/L \times y)^2$$

So, kinetic energy of the whole spring $= \int_0^L \frac{1}{2} \left(\frac{msV^2}{L^3}\right) y^2\, dy$

$$= 1/2 \times m_sV^2/L^3 \times L^3/3$$

$$K.E. = 1/6 \times m_sV^2$$

4.2.4 Calculation for the natural frequency of the system:

The frequency at which a system oscillates when not subjected to a continuous or repeated external force is known as the natural frequency.

Displacement of spring mass system = a.

Velocity of slab = à.

Velocity of spring = à/Cos Ø

Mass of slab = M_s

Mass of single spring = m_s.

Stiffness of the spring = K.

Inclination of the spring with horizontal = Ø.

K.E. of slab = ½ M_s à².

K.E. of four springs = 4/6 (m_s /Cos²Ø) à².

Potential Energy of four springs = 4/2 K (a/Cos Ø)²

By using energy method

Total energy of the spring mass system:

E= K.E. of slab + K.E. of four springs + P.E. of four springs

= ½ (M_s à²) + 4/6 (m_s/Cos^{2}Ø) à² + 4/2 K (a/Cos Ø)²

On differentiating above equation wrt a, we get

M_s á ä + 4/3 (m_s/Cos^{2}Ø) á ä + 4(K/Cos^{2}Ø) a á = 0

On solving this equation, we get:

ä = -12 Ka/ (3M_s Cos^{2}Ø + 4m_s)

So, from above equation natural frequency of the system will be:

$w_{n =}$ { 12K/ (3M_s Cos^{2}Ø + 4m_s)}$^{1/2}$

Putting the various values in above equation we obtain:

w_n = 17.27 rad /sec.

$F_{n =}$ 17.27/ 2 × 3.14

= 2.75 Hz.

CHAPTER

5

Result and Conclusions

5.1 Result and Conclusions

Seismogram is visual record of arrival time and magnitude of shaking associated with seismic wave. Analysis of seismogram allows measurement of size of earthquake and measure the wave amplitude you have to take its logarithm and scale it according to the distance of the seismometer from the earthquake, estimated by the S-P time difference. The S-P time, in seconds, makes t. The equation behind this nomogram, used by Richter

$M = \log_{10} A\ (mm) + 3 \log_{10} [8\ t\ (sec)] - 2.93$

Seismic Energy:

The amount of energy radiated by an earthquake is a measure of the potential for damage to man-made structures. Theoretically, its computation requires summing the energy flux over a broad suite of frequencies generated by an earthquake as it ruptures a fault. Magnitude is related to the amount of energy that is radiated by an earthquake. Gutenberg and Richter (1956) , developed a relationship between magnitude and energy Their relationship is:

$Log_{10} S = 11.8 + 1.5M$

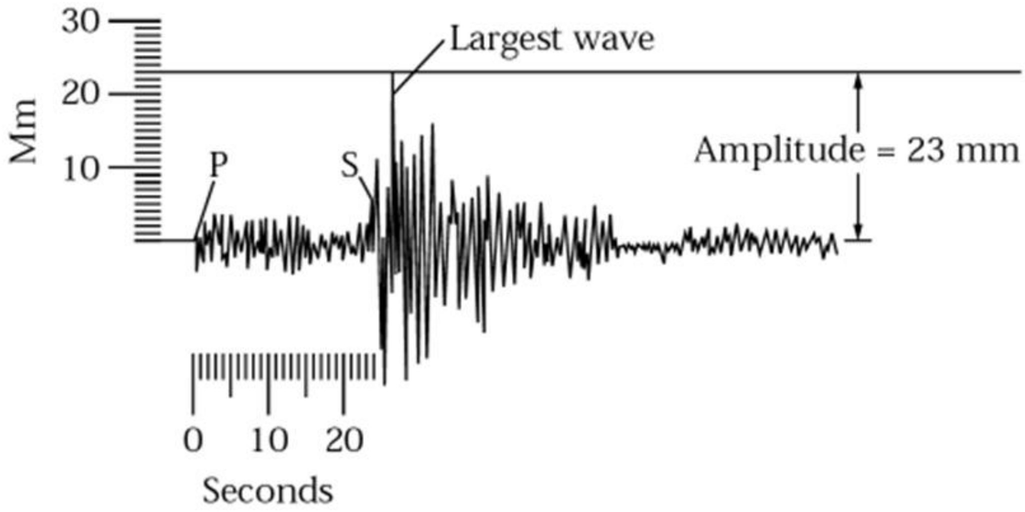

FIGURE 5.1: Amplitude-Time graph [20]

Graph gives us various data related to amplitude and time and using above equation we can find magnitude and seismic energy released of the earthquake.

Energy of earthquake required to hit the first scale:

$E_1 = ½ \ K_{eq} \times (Xs^1)^2$

$= 2.65 \times 10^{-2}$ joule

Energy of earthquake required to hit the second scale:

$E_2 = ½ \ K_{eq} \times (Xs^2)^2$

$= 10.6 \times 10^{-2}$ joule

Energy of earthquake required to hit the third scale:

$E_3 = ½ \ K_{eq} \times (Xs^3)^2$

$= 15.9 \times 10^{-2}$ joule

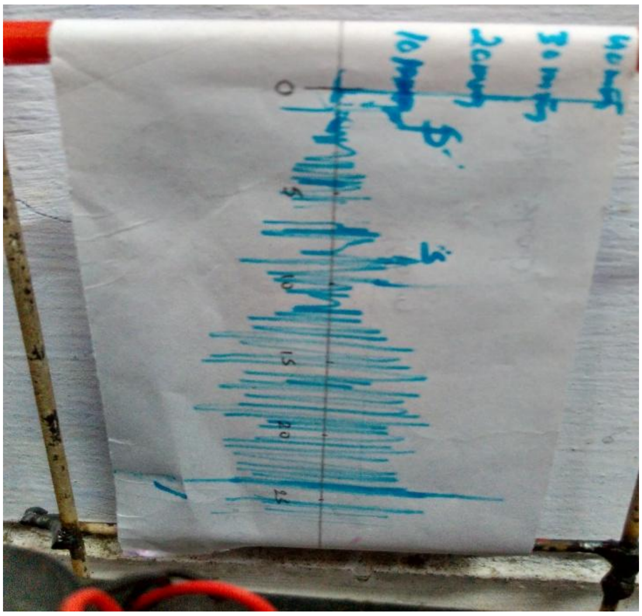

FIGURE 5.2 Amplitude-Time Graph

Based on above graph, data are as follows:

TABLE 2 Observation Table

AMPLITUDE (mm)	TIME (second)	MAGNITUDE $M=\log_{10} A(mm)+3\times\log_{10}(8\times t_{sec}) - 2.93$ (Richter)	SEISMIC ENERGY $\log_{10} S= 11.8 + 1.5m$ $S= 10^{11.8+1.5m}$ (Joule)
15	8	3.66	1.94×10^{10}
20	15	4.64	5.19×10^{11}
32	24	5.42	8.66×10^{12}

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